Transmittance measurements on variable coatings with enhanced spatial resolution

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An apparatus for localized transmittance measurements of optical coatings with spatially non-uniform performance is presented. The setup allows spectral acquisition in the range of 400–1000 nm with spatial resolution higher than 20 μm. Examples of its implementation for the characterization of linearly variable optical components of portable spectrometers are given.

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Optical coatings for specific applications where an intentionally designed non-uniform surface induces spatially variable optical performance may have performance variations at a micrometer scale. To characterize the optical devices of this kind, a dedicated measurement technique is required to allow surface mapping of optical behavior. As long as commercial spectrophotometers have insufficient spatial resolution for acceptable results, dedicated apparatuses are needed for localized measurements.

Recently, two instruments developed for localized photometry were compared[1]. In this letter, we present a novel setup with an extremely simplified construction for the purpose of transmittance measurement with enhanced spatial resolution and high spectral accuracy. Any type of structured material for which the transmittance is not constant over the surface can be measured by this apparatus, from biological samples to components for space applications.

To illustrate the functionality of the proposed instrument, this study analyzes the optical performance of linearly variable filters manufactured in the frame of research programs for spatial applications. Such filters[2,3] are employed for the construction of miniaturized spectrometers for image spectroscopy of Earth and other planets from space. In particular, we report on the characterization of two different types of filters: an induced-transmittance narrowband filter with linear variation of a transmittance peak over the surface and an all-dielectric low bandpass filter with nonlinear spatial profile. The filter transmission peak in the first case, as well as the edge of the pass-band in the second case, are moved from a minimum to a maximum wavelength (430–930 nm and 300–900 nm, respectively) over a spatial length of a few millimeters, with a gradient of about 200 nm/mm.

The measurement setup (Fig. 1) consists of illuminating and collecting optics and a spectral analyzer connected to the computer. The radiation from a hybrid deuterium-tungsten source is delivered by an optical fiber with a 5 μm in-diameter core to the sample surface. The output fiber end is positioned at a distance of less that 1 mm from the sample to avoid scratching the fiber against the sample surface during the sample movement. At this distance, the numerical aperture of the illuminating fiber guarantees a light spot size less than 20 μm. The two-dimensional translation micrometric system insures accurate sample positioning for bi-dimensional scanning with a minimum motor step of 0.25 μm. A lens block focuses the transmitted light onto the entrance of a fiber with a 600 μm core, which is connected to the Ocean Optics HR2000 spectrometer. This spectrometer allows signal acquisition in the range of 300–1100 nm with a resolution of 2 nm. These range extremes are actually slightly shortened to 400–1000 nm due to a relatively high noise-to-signal ratio caused both by a low signal level (small core of illuminating fiber and non-optimized fiber-to-lamp connection) and a lower sensitivity of the spectrometer at the extremes of its working range. Both spectral range and spatial resolution may be improved if a spectrometer with an enhanced spectral resolution and sensitivity is employed or if the gap between the sample and the illuminating fiber is decreased.

Both analyzed filters are multilayer optical coatings deposited on glass substrates. The first coating is comprises 21 alternating layers of silicon oxide and tantalum

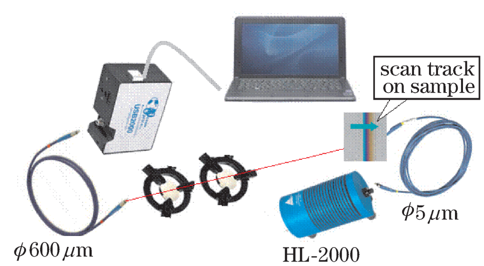

Fig. 1. Transmittance measurement setup.

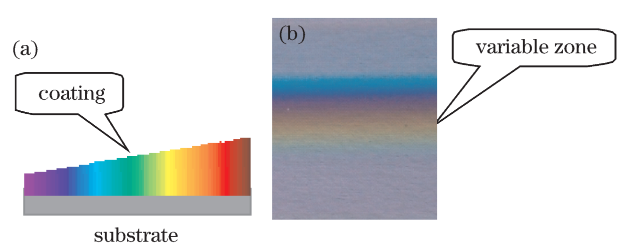

Fig. 2. (a) Side view (model) of a variable thickness coating; (b) picture of the surface of the variable filter.

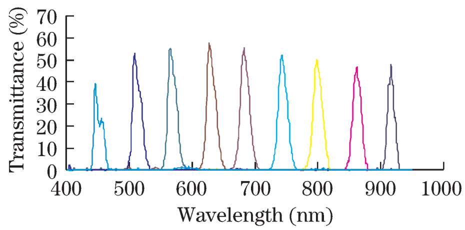

Fig. 3. Measured transmittance at different positions along the surface of the linearly graded narrow-band induced-transmittance filter.

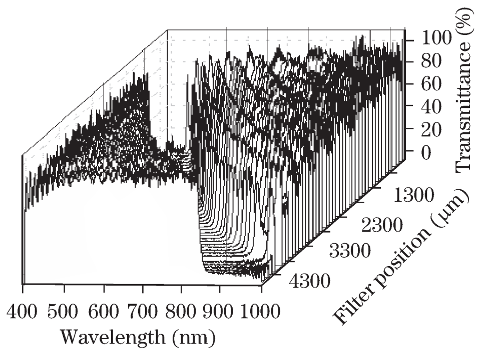

Fig. 4. Measured transmittance at different positions along the surface of the nonlinearly graded low bandpass filter.

oxide, with a thin silver layer in the middle (the induced transmittance filter)[4]. The thickness of each layer is in the range of tens to hundreds of nanometers, and the total thickness of the whole stack depends on the peak wavelength of the filter. Hence, it changes over the filter surface (Fig. 2(a)). A picture of the variable filter, with color stripes due to interference, is shown in Fig. 2(b). In practice, the coating thickness variation following a required profile (necessarily linear in this case) is obtained by introducing suitable masks inside the deposition system[2].

In the second case, the filter consists of 38 alternating tantala and silica layers. The equation that describes the spatial performance of the band-pass filter is nonlinear. Hence, the corresponding thickness profile is calculated according to this requirement.

The transmittance spectra were acquired along the direction of variation of both filters. The results are shown in Figs. 3 and 4.

In conclusion, the proposed setup allows accurate characterization of coatings with non-uniform surface transmittance distribution. Although both spatial and spectral resolutions of the proposed setup may be further improved, the instrument characteristics are suitable for the measurement of variable filters with a passband as narrow as 10 nm and a spatial slope as steep as 200 nm/mm.

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